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A research project was aimed at measuring the relationship between infant vocalizations and linguistic development and determining the feasibility of using infant vocalizations as a predictor of later psychological and intellectual status. However, a method was needed to analyze the vocalizations of infants. This report describes a method used to analyze the vocal behavior of infants in their prelinguistic stage, from birth to 4 months. The method was based on the "distinctive features" concept. Eight distinctive features of infant vocalization were coded by observers. This data yielded information on the quality and frequency of infant vocal behavior and provided a measure of individual differences between prelinguistic infants. Data have been collected on forty 3-day-old infants. This eight-feature coding scheme has proven to be reliable. (WD)

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A Distinctive Features Analysis of Pre-Linguistic Infant Vocalizations

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This is the first report of a research project studying the behavioral correlates of infant vocalizations.[1] The investigators are recording at regular intervals the vocalizations of infants beginning a few days after birth and continuing until the subjects are two years old. Speech and intellectual development of the infants are assessed when the subjects are three years of age. The ultimate aims of this project are to measure the relationship between infant vocalizations and linguistic development, and to determine the feasibility of using infant vocalizations as a predictor of later psychological and intellectual status. This report describes the method that was used to analyze the vocalizations of three-day-old infants, which were obtained in the hospital nursery. All subsequent recordings were made in the infants' homes.

Previous phonetic and spectrographic analyses of the vocal behavior of infants in their "pre-linguistic" stage, from birth to approximately four months (Irwin, 1957; Lenneberg, 1962), were felt to be either inappropriate, inordinately time-consuming, or limited in the number of relevant variables that could be obtained. The major difficulty with a phonetic transcription of pre-linguistic infant vocalizations is that the non-linguistic characteristics of these vocalizations are not identified, e.g., the length of the vocalization, the direction of the air stream, and the force of the air stream.[2] The major difficulties with using the sound spectrograph to study pre-linguistic vocalizations are the limitation of the size of any given sample of sound that can be analyzed at one time (2.4 seconds), the lack of reliable evidence for measuring acoustic variables other than frequency, intensity, and duration, and the inability to convert spectrograms of infant vocalizations into meaningful linguistic data, such as the phonemes that are being approximated by the infant.

Given these considerations, a method to code infant vocalizations was developed based on the "distinctive features" concept of Jakobson, Fant and Halle (1952). The description of any sound in terms of the following distinctive features includes all of the information given by a symbol in the International Phonetic Alphabet (I.P.A.), and in most cases it

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includes additional information that is not given by these symbols. However, for the acoustic variables of frequency, intensity, and duration, the corresponding features are probably not as precise as would be obtained with a sound spectrograph. The eight distinctive features are: (1) vocalization (sound vs. silence), (2) length of sound (short vs. long), (3) length of silence (short vs. long), (4) direction of air stream (egressive vs. ingressive) (5) air passage (oral vs. nasal),(6) muscular tension (lax vs. tense), (7) force of air stream (soft vs. loud), (8) vocal cord vibration (voiced vs. voiceless). The present paper reports the results of applying this method to the vocalizations of 40 three-day-old infants.

Method

A. Definition of the Eight Distinctive Features.

1. Vocalization (sound/silence).

Any audible vocalization produced by the infant is coded as one <u>sound</u> regardless of duration. Audible, but unobstructed, breathing is coded as <u>silence</u>. Any perceptible silence or "break" is considered the end of one sound.

2. Length of Vocalization (short/long).

Duration of the word"pit" as it is normally pronounced in isolation is used as the standard of measurement. If the sound is the same duration or shorter than "pit" the sound is coded <u>short</u>; if the duration of the sound is longer than "pit" it is coded <u>long</u>.

3. Length of Silence Between Vocalizations (short/long).

The duration of the silence between sounds is coded <u>short</u> or <u>long</u> following the same procedures as in 2, above.

4. Direction of Air Stream (egressive/ingressive).

If the air stream is expelled outward the sound is coded egressive; if the sound is produced by inhalation of air it is coded ingressive.

5. Air Passage (oral/nasal).

If the air stream passes through the oral cavity, with complete or partial velvic closure, the sound is coded <u>oral</u>; if the velum is lowered and the oral cavity closed at some point, so that the air stream passes through the nasal cavity, the sound is coded <u>nasal</u>. By definition, therefore, sounds which are partially nasal would be considered <u>oral</u>.

6. Muscular Tension (lax/tense).

If the sound is made with relatively relaxed muscles in the mouth and throat it is coded lax; if the sound is made with relatively tense muscles in the mouth and throat it is coded tense.

7. Force of Air Stream (soft/loud).

The loudness of adult conversational speech is used as the standard of measurement. If the sound is equal to, or softer than this standard it is coded soft; if the sound is louder than this standard it is coded loud.

8. Vocal Cord Vibration (voiced/voiceless).

If the sound has any quality of pitch caused by vocal cord vibration it is coded voiced, if the sound has no quality of pitch it is coded voiceless.

B. Transcription Sheet

The following is a sample of the transcription sheet that is used to code the eight distinctive features. Vocalizations are indicated by checking the Arabic numerals. Beneath each Arabic numeral the distinctive features of that particular sound are coded: length of vocalization (s/l); direction of air stream (e/i); air passage (o/n); muscular tension (l/t); force of air stream (s/l); vocal cord vibration (v/u). Length of the silence between vocalizations is coded (s/l) between the Arabic numerals.

Segment No._____

1	s/l	2	s/l	3	s/l	4	s/l	5	s/l	6	s/l	7	s/l	8	s/l	9	s/l	10	s/l	11	s/l
s/l		s/l		s/l		s/l		s/l		s/l		s/l		s/l		s/l		s/l		s/l	
e/i		e/i		e/i		e/i		e/i		e/i		e/i		e/i		e/i		e/i		e/i	
o/n		o/n		o/n		o/n		o/n		o/n		o/n		o/n		o/n		o/n		o/n	
l/t		l/t		l/t		l/t		l/t		l/t		l/t		l/t		l/t		l/t		l/t	
s/l		s/l		s/l		s/l		s/l		s/l		s/l		s/l		s/l		s/l		s/l	
v/u		v/u		v/u		v/u		v/u		v/u		v/u		v/u		v/u		v/u		v/u	

C. Time Signals.

A major obstacle in coding infant vocalizations is the difficulty of keeping track of the vocalizations, both while the individual coder is transcribing and also in attempting to compare the transcriptions of two coders. Contrary to language, there are no "words" on which the transcriber can focus. To overcome this difficulty a copy of the original recording is made and a consecutive number read on to the copy at approximately every five seconds. This division of the recordings into five second "segments" has proven to be an excellent solution to the problem of focusing on any given vocalization.

D. Training Tape.

After the eight distinctive features had been operationally defined, two coders independently coded the recordings of four of the infants.[3] The infants used in this stage were selected impressionistically to represent different types of vocalizations after the coders had listened to the entire sample of the recordings of the three day old infants. A training-tape was then made containing (1) samples, out of context, contrasting the distinctive features, and (2) the actual vocalizations of four infants segmented by time signals. A manual with the "correct" transcription was prepared to accompany this tape. In all, the training tape consists of 39 segments of four infants, with a total of 216 vocalizations to be coded.[4]

E. Subjects.

The subjects for this study were selected from the sample of infants entering the Collaborative Study of Cerebral Palsy and Other Neurologic and Sensory Disorders of Infancy and Childhood, at the Children's Hospital, Buffalo, New York.[5] All subjects met the following criteria: white native-born parents; birth weight 2500 to 400 grams; 37 to 42 weeks gestation period; rating of 7+ on the Apgar scale of neonates; no placental separation; heart beat of 120 to 160; and, no jaundice or erythroblastosis.

F. Recording.

A Wollensak Model 1515-4 portable tape recorder with the standard accessory microphone was used. Although the fidelity of this tape recorder is not as good as some available, it seemed the best suited for our purposes, primarily because of its mobility. Female

assistants were used to make all recordings to allow minimum interference in the infant's homes, and the size and weight of higher fidelity tape-recorders would have made these visits extremely difficult. Vocalizations of the three-day-olds reported in this paper were all made in the nursery at the Children's Hospital, Buffalo, New York. A room was provided adjacent to the nursery, and the babies were wheeled into this room in their basinettes. The microphone was hooked to the side of the basinette facing the infant. If for the first five minutes the infant had not produced any vocalizations, the experimenter "flicked" the infant's foot and allowed the recorder to run for another five minutes.

Results

A. Reliability of Coding

Two estimates of the reliability of the coding procedure were obtained. In the first, the results of two coders working independently were compared. In the second, the final transcription agreed upon by one team of two coders was compared to the final transcription agreed upon by a second team of two coders. The second team of two coders had no specialized training in linguistics, and had been taught the coding procedures by listening to the training tape and following the manual. For both estimates of reliability the final transcriptions for one infant were compared.

An important aspect of the coding procedure should be noted at this time. The first feature to be coded is vocalization (sound/silence). After each coder has determined, independently, the number of sounds in one segment, the transcriptions are compared. At this point the coders attempt to arrive at agreement as to the number of sounds in each segment, to make certain they are describing the distinctive features of the same sounds. This procedure must be followed if the description of the distinctive features of the sounds are to be compared. Disagreements as to the number of sounds arise primarily because (1) there are often sounds on the tape which are difficult to categorize as produced by the infant or as "noise"; (2) some sounds are so faint that a coder may fail to hear them until attention is called to them; and (3) the "break" in a sound may be so brief that it is not noticed until attention is called to it. Because of these problems a separate estimate of the reliability of determining the number of sounds is reported.

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1. Reliability of Two Coders.

a. Number of Sounds.

The total number of sounds recorded by both coders was 153, and there were 22 disagreements. A disagreement in this instance means that one coder indicated a sound where the second coder did not. If both coders agreed that there was silence for an entire segment it was counted as one agreement. There were four such segments on this tape, which means there was a total of 127 sounds to be coded. Since both coders agreed on 131 out of the 153 sounds there was 86 percent agreement between the two coders for indicating the occurrence of sounds.

b. Distinctive Features.

After reaching agreement on the number of sounds in each segment, the coders independently coded the distinctive features of each sound. Since there were 127 sounds, a decision about each of the 7 other distinctive features had to be made 127 times, for a total of 889 decisions. Table 1 indicates the percentage of agreement for each distinctive feature.

2. Reliability of Coding on Two Occasions by Two Different Teams of Coders.

a. Number of Sounds.

The total number of vocalizations (sound/silence decisions) agreed upon by the two coders on Occasion 1 was 143, and the total number of sounds agreed upon by a second team of two coders on Occasion 2 was 131, indicating 92 percent agreement as to the number of sounds.

b. Distinctive Features.

Although the percentage of disagreement in coding the number of sounds is small (8%), what disagreements there were made it difficult to compare the coding of the distinctive features in many segments. That is, if one team had coded 5 sounds in a given segment and the second team had coded 6 sounds for that segment, it was impossible to compare the coding of the distinctive features for that segment. There were, however, 45 sounds that could be directly compared from the transcripts, and Table 2 indicates the percentage of agreement between the two teams of coders for these 45 sounds.

Table 1

Percentage of Agreement for Coding the Distinctive Features of 127 Sounds for Two Coders

Distinctive Feature	No. Agreements	Percentage Agreement
Length of Sound	124	98
Length of Silence	121	95
Direction of Air Stream	118	93
Air Passage	127	100
Muscular Tension	110	87
Force of Air Stream	117	92
Vocal Cord Vibration	116	91
Total No. Decisions	889	94

Table 2

Percentage of Agreement Between Two Teams of Coders on Two Different Occassions Coding the Distinctive Features

Distinctive Feature	No. Agreements	Percentage Agreement
Length of Sound	45	100
Length of Silence	39	87
Direction of Air Stream	43	96
Air Passage	45	100
Muscular Tension	38	84
Force of Air Stream	41	91
Vocal Cord Vibration	40	89
Total No. Decisions	315	92

B. Preliminary Normative Data

The distinctive feature analysis described above was applied to the vocalizations of 40 three-day-old infants. The recordings were sampled so that the first, third, fifth, seventh, and ninth sequence of ten consecutive segments were coded. Thus, segments 1-10, 21-30, 41-50, 61-70, and 81-90, were included. Since each segment is approximately 5 seconds in length, each sample consists of at least 50 seconds of continuous recording, and the results reported are based on at least 4.2 minutes of recording for each infant. Table 3 indicates the results obtained for 40 three day olds.

Discussion

This paper describes a method for coding the vocalizations of infants in the pre-linguistic stage of development. The introduction indicated the reasons for developing a coding technique based on distinctive features, rather than using phonetic or spectrographic analyses, but we do not view a distinctive features analysis as mutually exclusive of either of these methods. Irwin's studies (1957), and a preliminary examination of our own tapes indicate that at about three to four months of age a classic phonetic transcription can be meaningfully applied to infant vocalizations. We plan to carry our distinctive features analysis beyond this stage, and through this method we should be able to see the development of the phonetic system in the shifts in the kind, number, and combinations of distinctive features. Lenneberg (1962) has indicated that in addition to frequency, intensity, and duration, he can discriminate vocal cord modulation, modulation by constriction of the air tunnel, modulation by resonance, and modulation by interruption of the air stream, from spectrograms. Again, if there is validity to a distinctive features analysis there should be some correlation between the distinctive features and the spectrographic data. It may be that the application of both the spectrograph and distinctive feature analysis will yield the maximum amount of information concerning pre-linguistic infant vocalizations.

At the present time the distinctive features analysis has produced data that will be meaningful to the study of the relationships between infant vocalizations and later linguistic and psychological development. The results indicate that a distinctive features analysis is reliable, that it yields normative data on the quality and frequency of infant vocalizations, and, that it provides measures of individual differences between infants in the pre-linguistic stage.

Table 3

Normative Data on 40 Three Day Olds Based on 4.2 Minutes for Each Infant

Sub. No.	Vocalization No. sounds*	Silence % short	Sound % short	Direction % egressive	Passage % oral	Tension % lax	Force % strong	Vocal Cords % voiced
1	4.10	60	66	94	100	14	67	78
2	0.62	29	94	90	97	35	100	71
3	5.90	94	48	59	100	18	45	86
4	0.28	7	79	71	64	29	100	86
5	2.10	61	92	78	96	21	85	78
6	3.20	72	91	88	84	52	95	57
7	1.50	38	100	97	96	36	100	41
8	4.00	88	76	91	95	22	79	80
9	1.70	57	90	92	92	49	98	56
10	2.10	73	68	94	98	45	99	56
11	5.60	77	33	80	90	4	34	82
12	2.10	33	99	98	89	53	100	33
13	3.30	92	65	64	100	5	68	95
14	0.60	37	97	93	37	63	100	27
15	2.00	64	79	86	92	29	66	79
16	1.30	33	97	94	100	85	100	25
17	2.30	48	92	80	99	52	100	60
18	2.20	74	91	76	100	62	93	45
19	3.70	91	63	74	99	5	51	93
20	3.80	93	63	90	100	14	56	86
21	1.90	60	91	98	97	65	99	55
22	1.60	38	100	84	100	82	100	24
23	1.10	13	98	100	100	95	100	20
24	1.20	34	91	83	84	83	91	19
25	0.66	48	76	100	100	70	94	45
26	3.90	78	84	67	96	21	72	84
27	1.50	57	99	95	97	77	100	22
28	4.60	82	62	76	99	17	40	81
29	0.76	29	95	89	95	66	100	37
30	1.40	66	99	35	96	30	100	10
31	1.40	58	86	90	100	42	94	79
32	6.20	99	54	59	100	00	8	99
33	3.50	73	76	81	93	23	69	69
34	0.34	35	94	94	82	47	100	41
35	6.50	97	48	73	100	2	55	98
36	0.34	24	100	76	94	53	100	53
37	0.30	20	100	100	73	45	100	73
38	0.74	54	62	100	97	89	100	95
39	4.20	91	54	76	99	1	19	82
40	0.34	47	100	76	100	94	100	6

* Mean number of sounds per 5 second segment.

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Footnotes

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2. It is interesting to note that another research project studying pre-linguistic infant vocalizations has independently come to the same conclusion regarding the use of phonetic transcriptions (Bullowa, Jones, and Bever, 1964, p. 105).

3. The authors are indebted to Miss Susan Cohen, our research technician and analyst, for her assistance in developing the coding procedures.

4. The training-tape and manual are available upon request.

5. The authors would like to thank Dr. Milton Westfall, Director, Collaborative Project, Children's Hospital, Buffalo, New York, for his assistance in obtaining the subjects for this study.